Introduction to microbiology

General Microbiology - Lecture 1

Cañada College, Redwood City - Fall 2008

Instructor: Tamas Torok, Ph.D.

Berkeley Lab

Class logistics

- Introduction
- Class schedule
- Text books, syllabus
- Attendance, notes, tests
- Problems
- Class objective

Class motto

"No one lights a lamp in order to hide it behind the door: the purpose of light is to create more light, to open people's eyes, to reveal the marvels around."

Paulo Coelho (Brazilian author)

***"The witch of Portobello"* (2006)**

Topics for today

- Microbiology - what is it?
- Short history of microbes and microbiology
- Microbial universe
  - what is a microorganism
  - classification of microorganisms
  - main domains of life

Micro-facts

- **"… 1 g of soil typically contains 1 million to 10 billion microbial cells representing about 4,000-10,000 species…"**

  (Torsvik et al., 1990)

- **Of all the cells that make up the normal, healthy human body, more than 99 % are the cells of microorganisms living on the skin, in the gut, *etc*.**

- **"…Microbial communities may constitute more than half of the biomass on Earth…"**

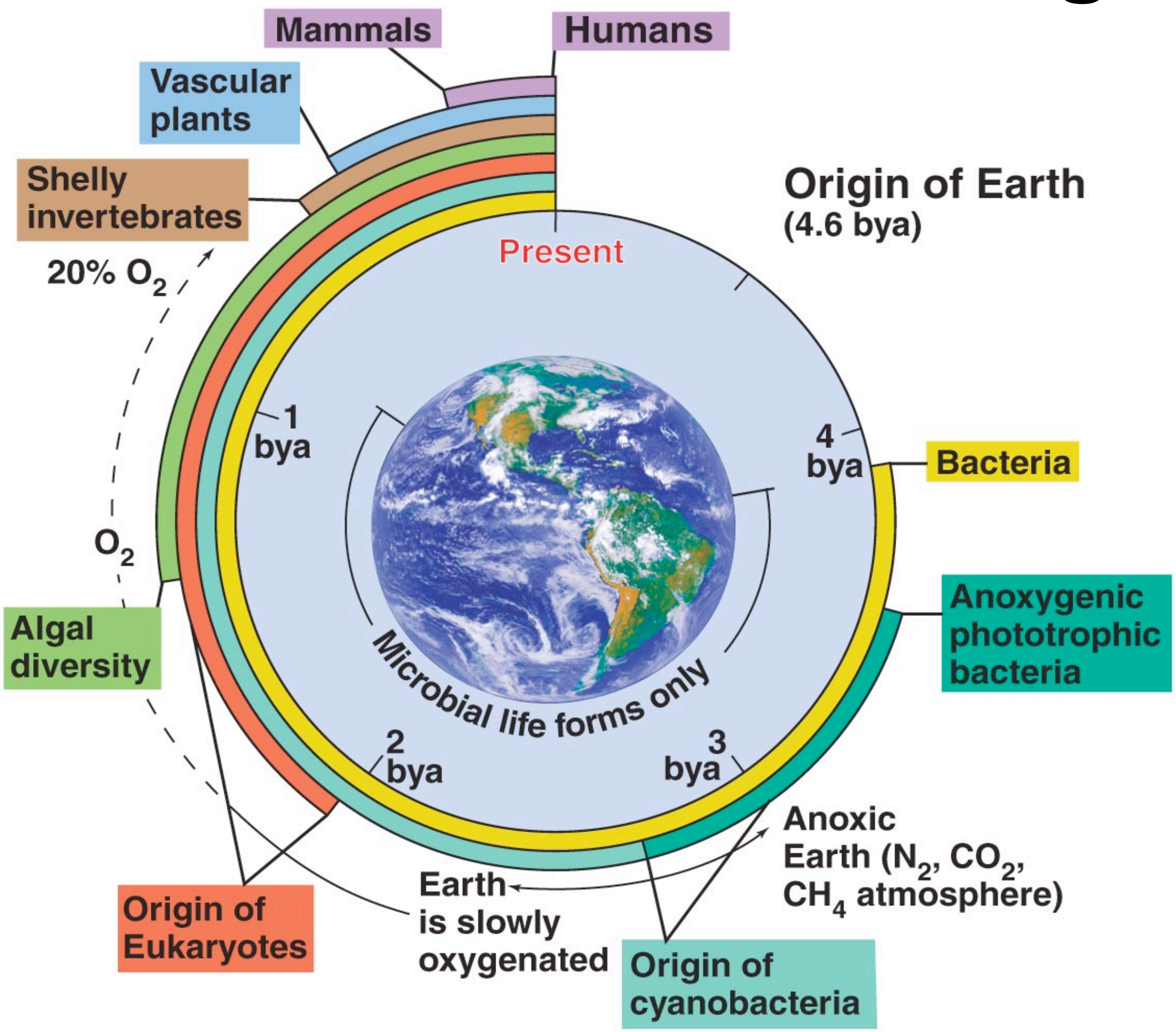
  (Whitman et al., 1998)

- **Microbes have survived on the planet for over 3.7 billion years and have been found in every conceivable (and inconceivable) environment, surviving extremes of heat, cold, radiation, pressure, salt, and acid - often where no other forms of life can exist**

Microbiology - what is it?

- Microbiology revolves around two themes
  - understanding basic life processes
    - microbes are excellent models for understanding cellular processes in unicellular ***and*** multicellular organisms
  - application of that understanding to benefit humankind
    - microbes play important roles in medicine, agriculture, and industry

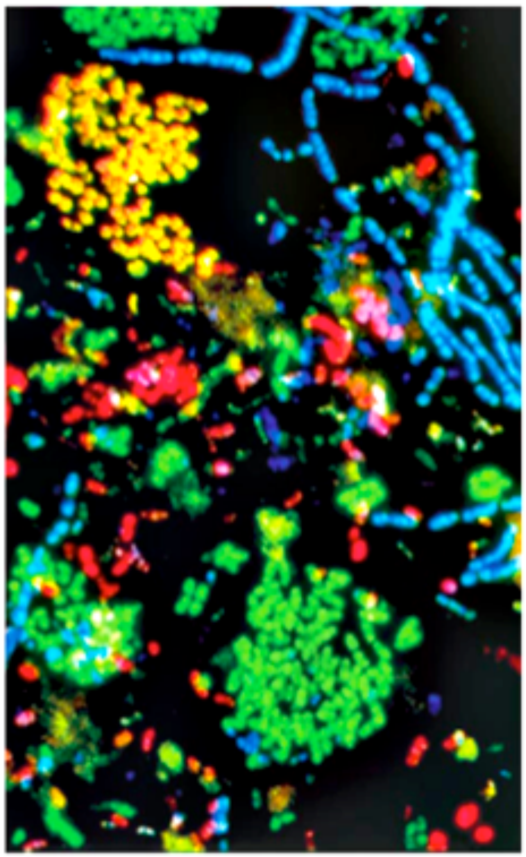
Life on earth through time



Microorganisms and their natural environments

- **Microorganisms exist in nature in populations of interacting assemblages called *microbial communities***
- **The environment in which a microbial population lives is its *habitat***
- ***Ecosystem* refers to all living organisms plus physical and chemical constituents of their environment**
- ***Microbial ecology* is the study of microbes in their natural environments**

Microorganisms and their natural environments



- **Diversity and abundances of microbes are controlled by resources (nutrients) and environmental conditions (*e.g.,* temperature, pH, O_2, *etc.*)**
- **The activities of microbial communities can affect the chemical and physical properties of their habitats**

Role of microorganisms

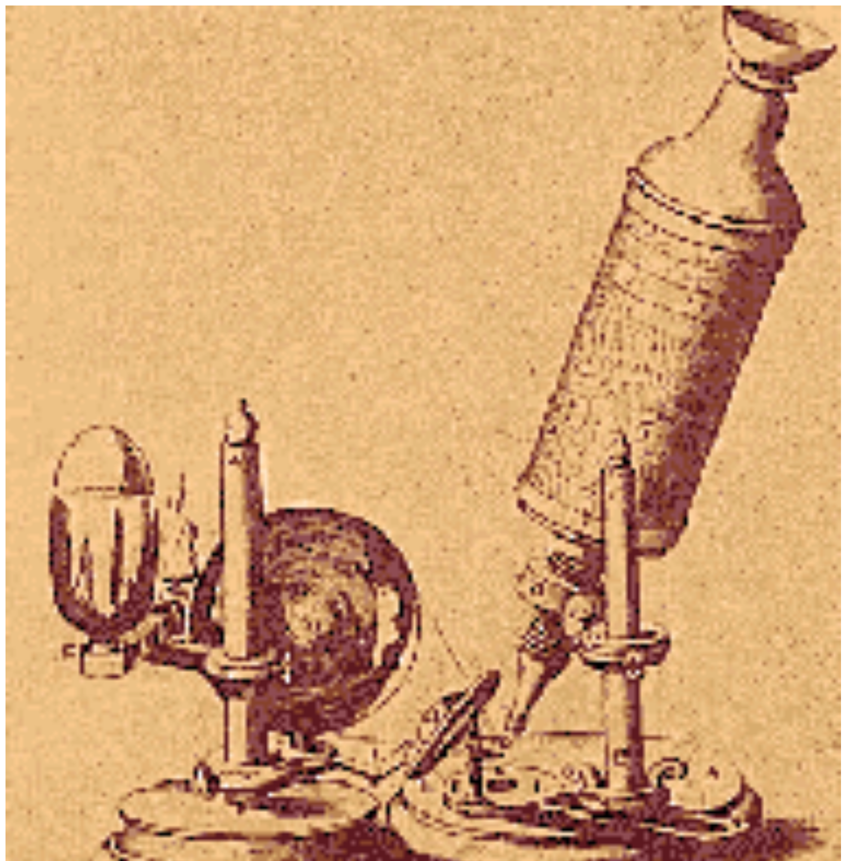
- "…Microorganisms are the foundation of the biosphere…"

(Norm Pace, 1999)

Time-line of microbiology

- 1677 - Antonie Leeuwenhoek observed "little animals”
- 1796 - Edward Jenner vaccinated against smallpox
- 1861 - Louis Pasteur disproved “spontaneous generation”
- 1881 - Robert Koch grew bacteria on solid media
- 1884 - Christian Gram developed his staining protocol
- 1928 - Alexander Fleming discovered penicillin
- 1953 - James Watson, Frances Crick, with the help of Maurice Wilkins and Rosalind Franklin, identified the physical structure of DNA
- 1957 - Francois Jacob, Jacques Monod, and Andre Lwoff described the regulation of protein synthesis in bacteria
- 1973 - Paul Berg, Herbert Boyer, and Stanley Cohen performed gene splicing
- 1977 - Walter Gilbert and Frederick Sanger discovered the method of DNA sequencing
- 1978 - Carl Woese described the three domains of life, Archaea, Bacteria, and Eucarya
- 1983 - Kary Mullis discovered PCR
- 1995 - TIGR sequenced the first microorganism, *Haemophilus influenzae*
- 2004 - First large-scale metagenomics project (Craig Venter et al.)

Robert Hooke's microscope (1665)



Antonie van Leeuwenhoek (1632 -1723)

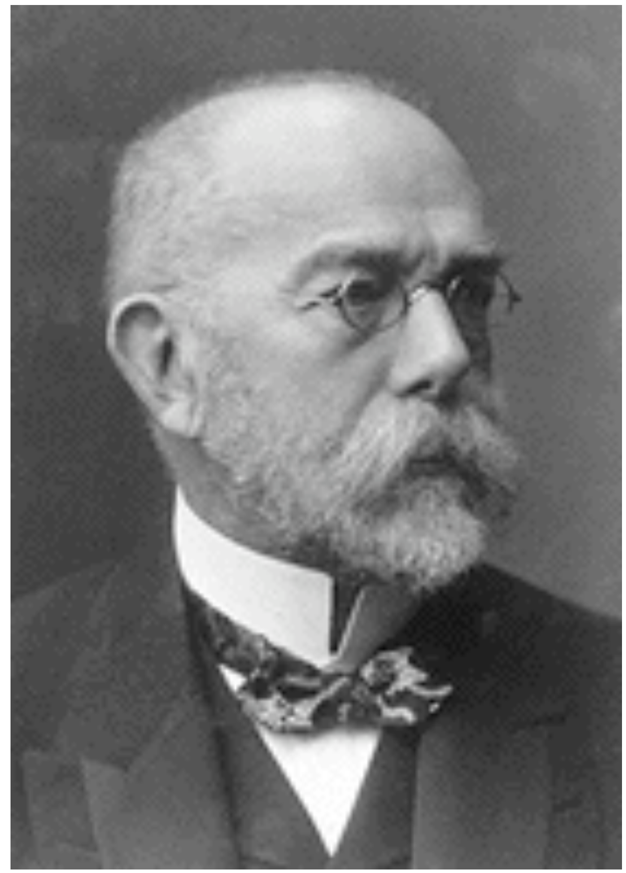
- Built over 500 “microscopes”
- Discovered bacteria, yeasts, free-living and parasitic microscopic protists, sperm cells, blood cells, and microscopic nematodes
- Communicated his discoveries for 50 years to the Royal Society of London

Louis Pasteur (1822-1895)

- Championed changes in hospital practice to minimize the spread of disease by microbes
- Discovered that weakened forms of a microbe could be used for immunization against more virulent forms of the microbe
- Found that rabies was transmitted by viruses
- Developed "pasteurization"

Robert Koch (1843-1910)

- Proved that *Bacillus anthracis* is the causative agent of anthrax - “germ theory”
- Invented techniques to obtain pure microbial cultures
- Discovered the causative agents of tuberculosis and cholera
- Worked on many human and animal diseases in Africa and India
- Received the Nobel Prize in Medicine in 1905



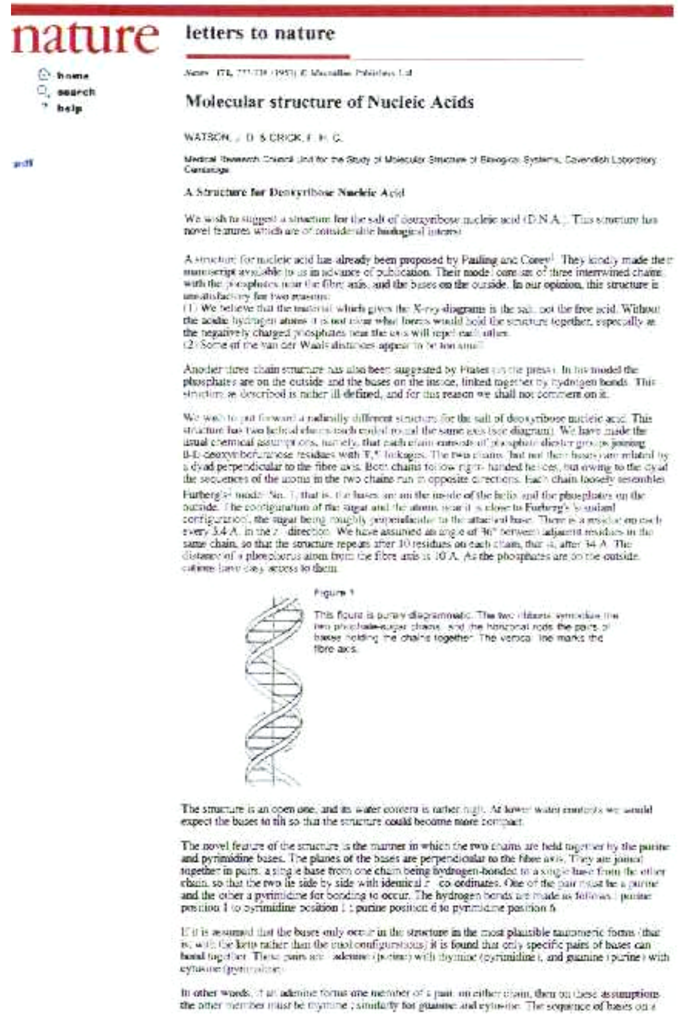
Paul Ehrlich (1854-1915)

- Ehrlich's theory: the antimicrobial capability of a molecule depended on its structure, particularly its side-chains
- Established chemotherapy with Salvarsan and Neosalvarsan, the most effective drugs for treating syphilis until the advent of antibiotics in the 1940s
- Nobel prize in medicine in 1908

Alexander Fleming (1881-1955)

- Experimented with hundreds of chemicals to treat infections
- "Private 606" during WWI
- Discovered penicillin production by *Penicillium notatum* in 1928
- Knighted in 1944
- Nobel Prize in 1945

James Watson and Francis Crick



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Molecular structure of Nucleic Acids

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A Structure for Deoxyribose Nucleic Acid

We wish to suggest a structure for the salt of deoxyribose nucleic acid (D.N.A.). This structure has novel features which are of considerable biological interest.

A structure for nucleic acid has already been proposed by Pauling and Corey[1]. They kindly made their manuscript available to us in advance of publication. Their model consists of three intertwined chains, with the phosphates near the fibre axis, and the bases on the outside. In our opinion, this structure is unsatisfactory for two reasons:
(1) We believe that the material which gives the X-ray diagrams is the salt, not the free acid. Without the acidic hydrogen atoms it is not clear what forces would hold the structure together, especially as the negatively charged phosphates near the axis will repel each other.
(2) Some of the van der Waals distances appear to be too small.

Another three-chain structure has also been suggested by Fraser (in the press). In his model the phosphates are on the outside and the bases on the inside, linked together by hydrogen bonds. This structure as described is rather ill-defined, and for this reason we shall not comment on it.

We wish to put forward a radically different structure for the salt of deoxyribose nucleic acid. This structure has two helical chains each coiled round the same axis (see diagram). We have made the usual chemical assumptions, namely, that each chain consists of phosphate diester groups joining β-D-deoxyribofuranose residues with 3',5' linkages. The two chains (but not their bases) are related by a dyad perpendicular to the fibre axis. Both chains follow right-handed helices, but owing to the dyad the sequences of the atoms in the two chains run in opposite directions. Each chain loosely resembles Furberg's[2] model No. 1; that is, the bases are on the inside of the helix and the phosphates on the outside. The configuration of the sugar and the atoms near it is close to Furberg's 'standard configuration', the sugar being roughly perpendicular to the attached base. There is a residue on each every 3.4 A. in the z-direction. We have assumed an angle of 36° between adjacent residues in the same chain, so that the structure repeats after 10 residues on each chain, that is, after 34 A. The distance of a phosphorus atom from the fibre axis is 10 A. As the phosphates are on the outside, cations have easy access to them.

Figure 1

This figure is purely diagrammatic. The two ribbons symbolize the two phosphate-sugar chains, and the horizontal rods the pairs of bases holding the chains together. The vertical line marks the fibre axis.

The structure is an open one, and its water content is rather high. At lower water contents we would expect the bases to tilt so that the structure could become more compact.

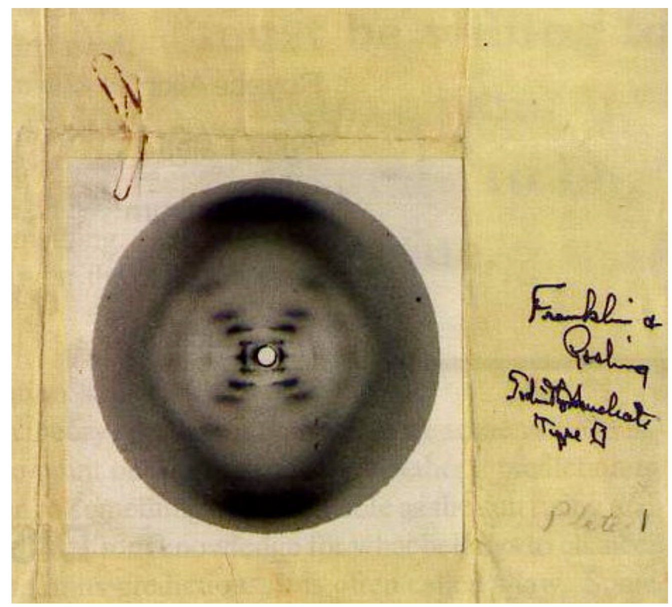
The novel feature of the structure is the manner in which the two chains are held together by the purine and pyrimidine bases. The planes of the bases are perpendicular to the fibre axis. They are joined together in pairs, a single base from one chain being hydrogen-bonded to a single base from the other chain, so that the two lie side by side with identical z-co-ordinates. One of the pair must be a purine and the other a pyrimidine for bonding to occur. The hydrogen bonds are made as follows: purine position 1 to pyrimidine position 1; purine position 6 to pyrimidine position 6.

If it is assumed that the bases only occur in the structure in the most plausible tautomeric forms (that is, with the keto rather than the enol configurations) it is found that only specific pairs of bases can bond together. These pairs are: adenine (purine) with thymine (pyrimidine), and guanine (purine) with cytosine (pyrimidine).

In other words, if an adenine forms one member of a pair, on either chain, then on these assumptions the other member must be thymine; similarly for guanine and cytosine. The sequence of bases on a

The missing third researcher

- **Rosalin Franklin was omitted from the *Nature* paper**
- **She was not credited by the Nobel Committee**



Kary B. Mullis

"...I went to high school in Columbia. I met my first wife, Richards, whom I married while I was working on a B. S. in chemistry at Georgia Tech. She bore Louise and I studied. I learned most of the useful technical things, math, physics, chemistry, that I now use, during those four years. I did little else, except to play with Louise and change her diapers at night. We moved to Berkeley, California in 1966. I did my Ph. D. in biochemistry under J. B. Neilands and there I learned the rest, the non-technical things. After that, it happened so quickly that it's hard to really talk about it…

Except for Cynthia and our boys.

I met Cynthia while I was in Kansas for three years. She's the very special daughter of an old grain trading family and a pathologist, David Gibson. Cynthia encouraged me to write and brought Christopher and Jeremy into the world. I left her, some say foolishly, when we were living in California in about1981.

I was working for Cetus, making oligonucleotides. They were heady times. Biotechnology was in flower and one spring night while the California buckeyes were also in flower I came across the polymerase chain reaction. I was driving with Jennifer Barnett to a cabin I had been building in northern California. She and I had worked and lived together for two years. She was an inspiration to me during that time as only a woman with brains, in the bloom of her womanhood, can be. That morning she had no idea what had just happened. I had an inkling. It was the first day of the rest of my life.

From there it's a single sentence. I worked as a consultant, got the Nobel Prize, and have now turned to writing. It is 1994…"

Microbial Marathon At Joint Genome Institute: Fifteen Organisms Sequenced In Single Month

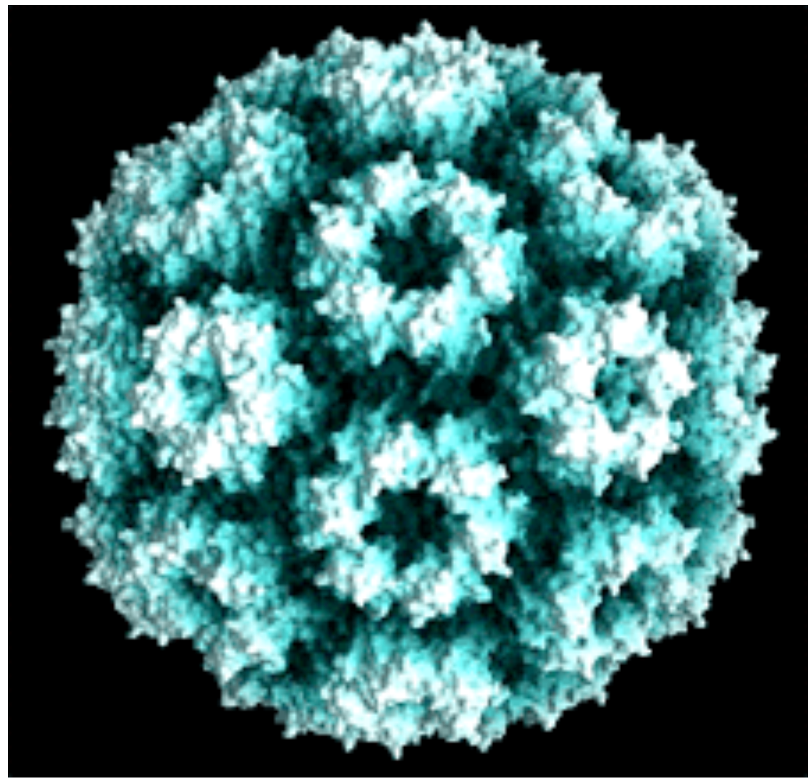
Paul Preuss, paul_preuss@lbl.gov

BERKELEY, CA — During the month of October, high-quality draft sequences of 15 bacterial genomes were produced at the U.S. Department of Energy's Joint Genome Institute (JGI) in Walnut Creek, California -- a rate of better than one genome for every one and a half working days.

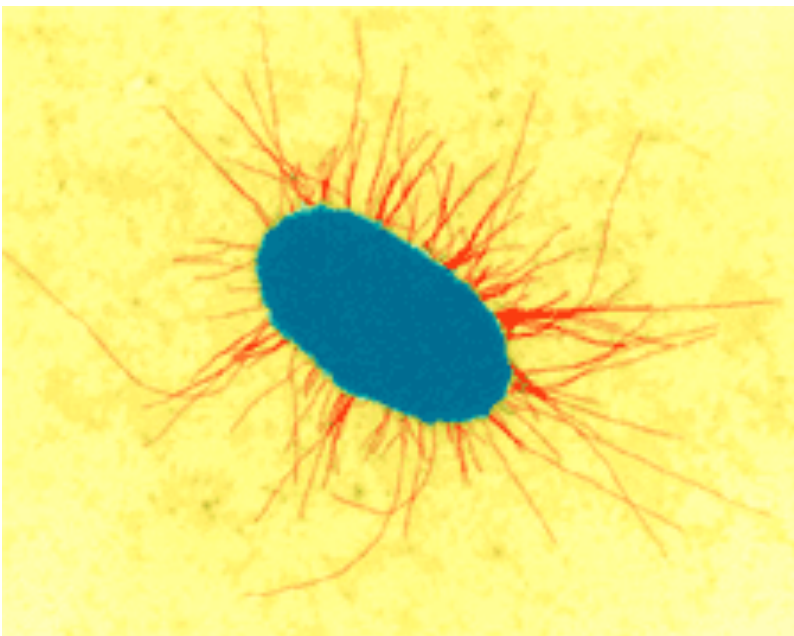
"This is a huge amount of data, a really diverse set of organisms, and a new approach to sequencing microbes," says Trevor Hawkins, deputy director of JGI and director of the Genomics Division at DOE's Lawrence Berkeley National Laboratory. Noting that only two dozen complete bacterial genome sequences have been published so far, Hawkins says that "by taking a sequence not to completion but to a high-quality draft representing more than 95 percent of the sequence, we can make essential data immediately accessible to biologists."

What is a microbe?

- **This is a cowpea virus, which infects certain bean plants**



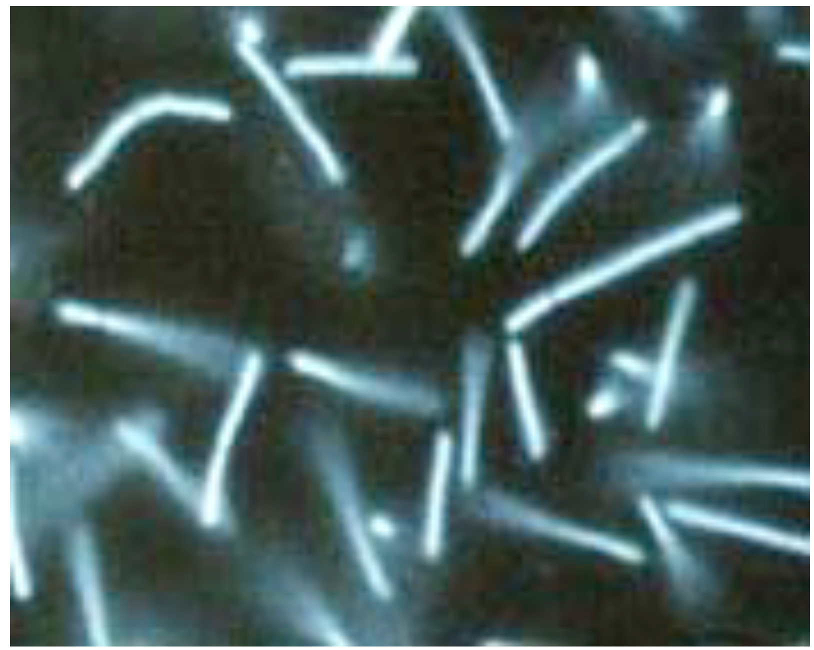
What is a microbe?



- This is a bacterium a.k.a. *Escherichia coli*
- Millions of *E. coli* live in our intestines
- They help our body digest the food we eat
- They also make certain vitamins our body needs

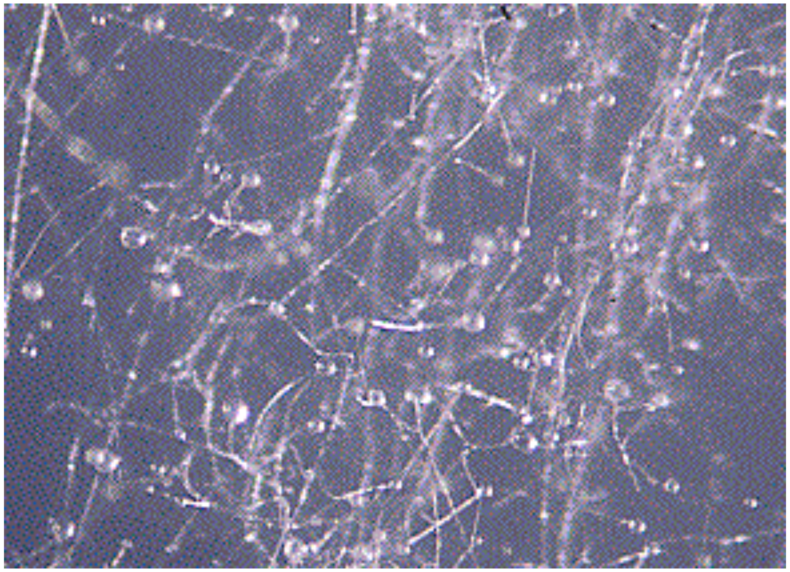
What is a microbe?

- These "bacteria-like" organisms represent a separate category of life
- Archaea are more like us than they are like bacteria



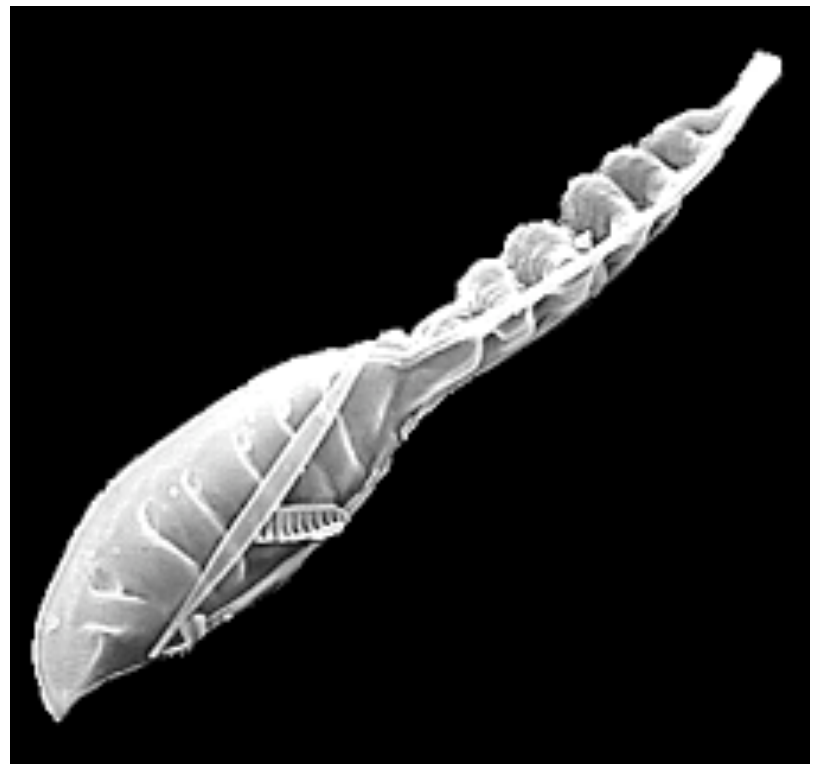
What is a microbe?

- **This is a macro-fungus, morel, everybody's favorite**

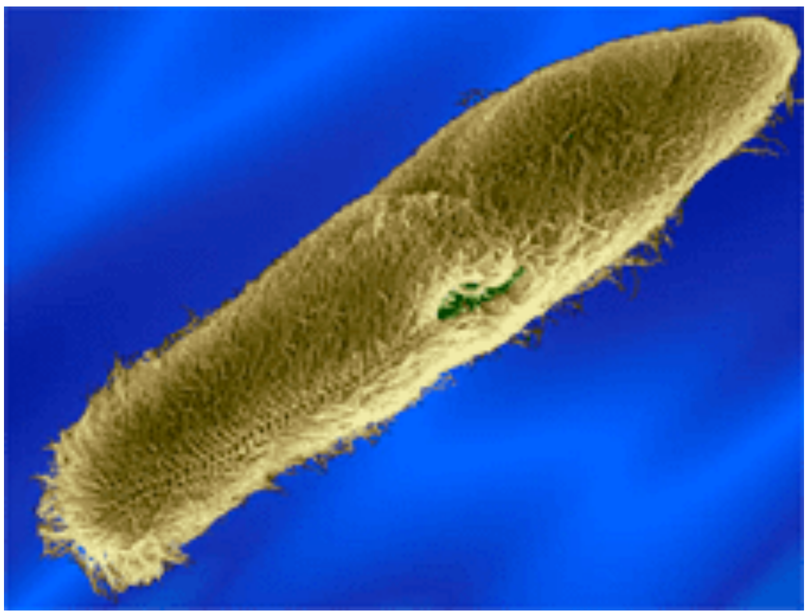


What is a microbe?

- **This single-celled creature is a form of an alga; a.k.a. diatom**
- **Diatoms live in fresh or ocean water**



What is a microbe?

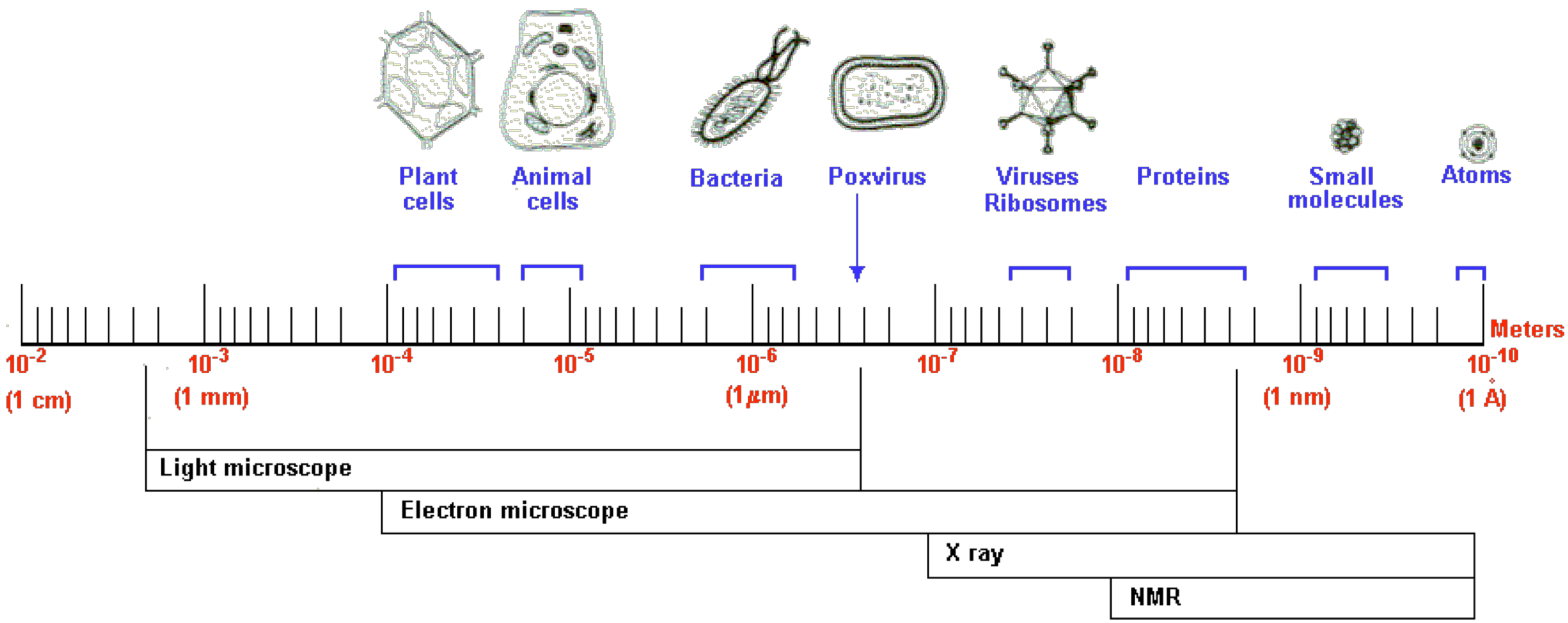


- **This is a protozoan called paramecium**

What is a microbe?

- Lichens are symbiotic associations between a fungus and a green alga or a cyanobacterium
- Their tolerance of environmental extremes enables them to colonize habitats where few other macroscopic organisms can grow

Scale of size in biology



Nomenclature of microorganisms

- Carolus Linnaeus [Carl Linné] (1707-1778)
  - Svedish botanist, physician, and zoologist
  - 1735-1738, he published the first edition of *Systema Naturae*, and laid the foundation of *binomial nomenclature* for naming a species
- Two names for each organisms
  - genus name is capitalized (*Escherichia*)
  - species name is in lower case (*coli*)
  - full name *E. coli*

Philosophy of classification

“...All wisdom is rooted in learning to call things by the right name. When things are properly identified, they fall into natural categories and understanding becomes orderly.”

Confucius (551-479 BCE)

Chinese thinker, political figure, and educator

Classification of microorganisms

- Classification is based on evolutionary development, cellular structure and function (Carl Woese, 1978)
  - Bacteria
  - Archaea
  - Eucarya

Bacteria

- Unicellular
- Chromosomal material is not enclosed by a nuclear membrane
- Peptidoglycan cell wall

Archaea

- Unicellular
- Chromosomal material is not enclosed by a nuclear membrane
- If cell wall is present, it lacks peptidoglycan
- Membrane fatty acids are branched and ether linked

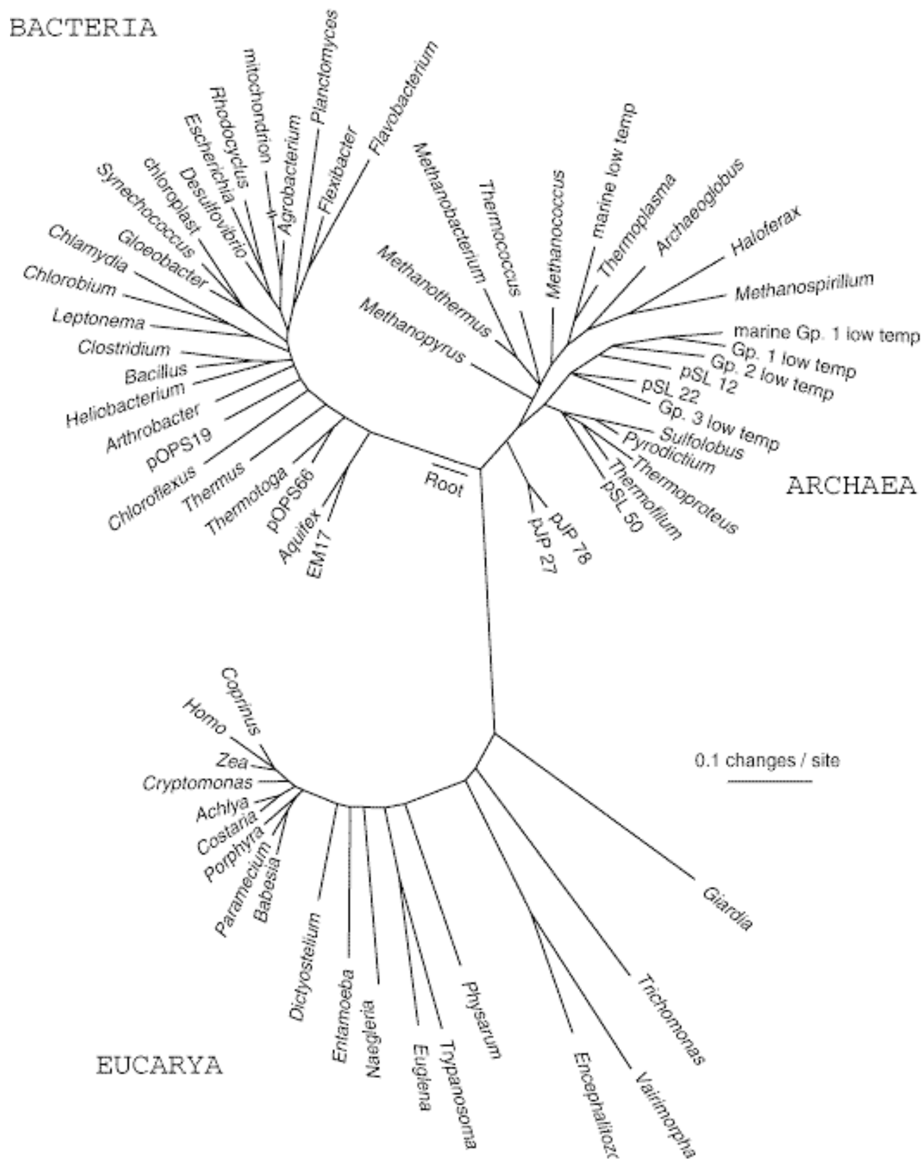
Eucarya

- Chromosomal material surrounded by a nuclear membrane
- Presence of membrane enclosed cell organelles

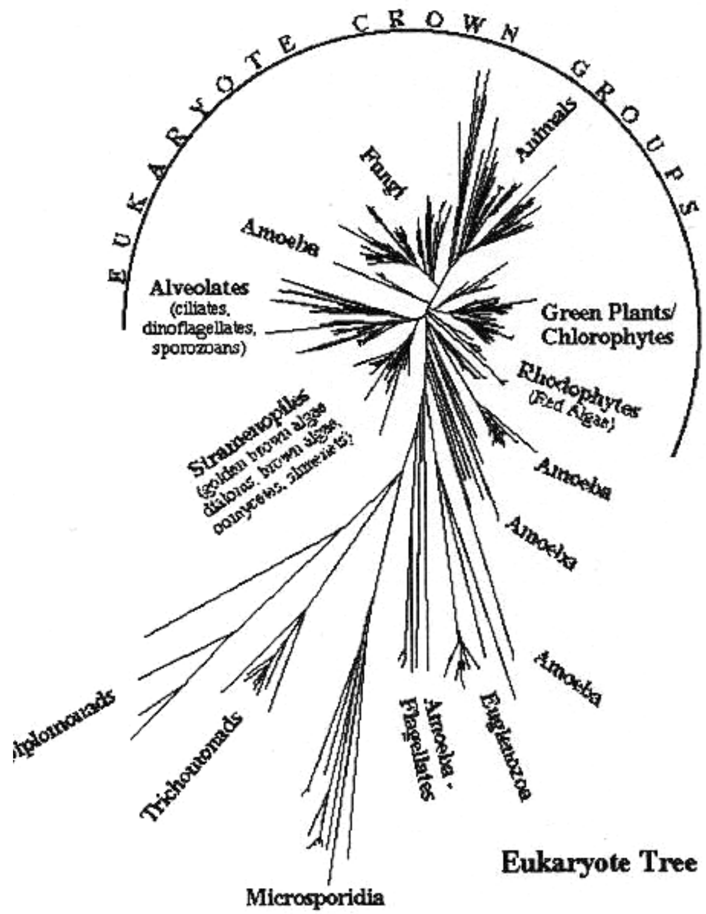
Viruses

- Electron microscopic-sized non-cellular structures
- Contain only one kind of nucleic acid
- Obligate parasites - reproduction in other organisms

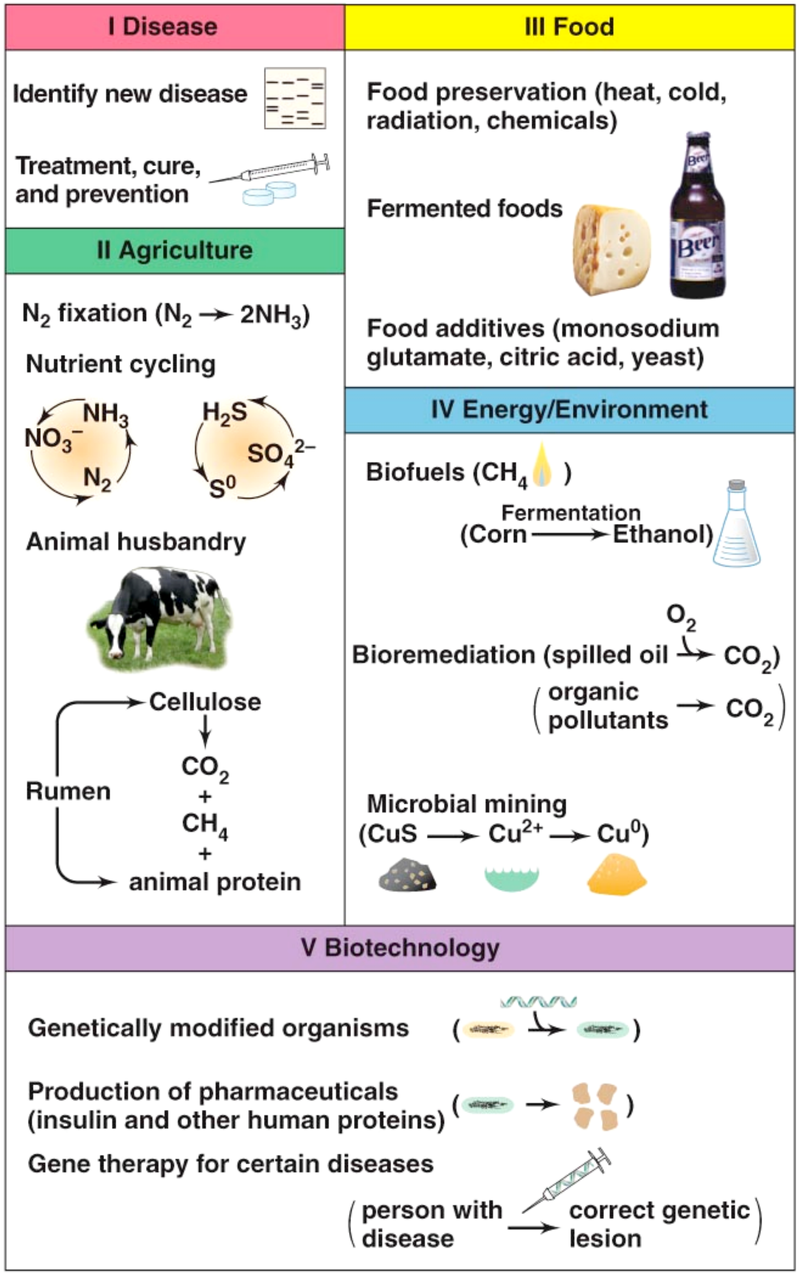
Tree of life



BACTERIA
mitochondrion
Planctomyces
Rhodocyclus
Escherichia
Agrobacterium
Flexibacter
Flavobacterium
Synechococcus
chloroplast
Desulfovibrio
Chlamydia
Gloeobacter
Chlorobium
Leptonema
Clostridium
Bacillus
Heliobacterium
Arthrobacter
pOPS19
Chloroflexus
Thermus
Thermotoga
pOPS66
Aquifex
EM17
Root
Methanobacterium
Thermococcus
Methanococcus
marine low temp
Thermoplasma
Archaeoglobus
Haloferax
Methanospirillum
Methanothermus
Methanopyrus
marine Gp. 1 low temp
Gp. 1 low temp
Gp. 2 low temp
pSL 12
pSL 22
Gp. 3 low temp
Sulfolobus
Pyrodictium
Thermoproteus
Thermofilum
pSL 50
pJP 78
pJP 27
ARCHAEA
0.1 changes / site
Coprinus
Homo
Zea
Cryptomonas
Achlya
Costaria
Porphyra
Paramecium
Babesia
Dictyostelium
Entamoeba
Naegleria
Euglena
Trypanosoma
Physarum
Encephalitozc
Vairimorpha
Trichomonas
Giardia
EUCARYA



EUKARYOTE CROWN GROUPS
Fungi
Animals
Amoeba
Alveolates
(ciliates, dinoflagellates, sporozoans)
Green Plants/ Chlorophytes
Rhodophytes
(Red Algae)
Stramenopiles
(golden brown algae, diatoms, brown algae, oomycetes, slime nets)
Amoeba
Amoeba
Amoeba
Trichomonads
Amoeba - Flagellates
Euglenozoa
Microsporidia
Eukaryote Tree



Future is today

- **Biology age - the sky is the limit**
  - biotechnology
  - disease prevention
  - gene therapy
  - understanding the origin of life
  - discovering life somewhere else

Death rates and the leading causes of death in the U.S.